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RCC METHODOLOGY/CODE EXTENSIONS (JUL 80): FAILURE MODEL, REPAIR/RETURN, AUGMENTED I/O AND DIVISION-LEVEL INTERFACING

J. Terrence Klopcic
Maureen McDonald

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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The BRL-developed RCC (Residual Combat Capability) methodology and code has been extended to include complex failure and repair/return-to-service models Also, an interface between RCC (detailed unit level) and a broad-scale division level model has been effected. This report describes these extensions, plus other user-oriented options which have been added to the RCC methodology and code since the preceding RCC report (ARBRL-TR-02196).

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I. INTRODUCTION

The genesis of the BRL-developed RCC (Residual Combat Capability) methodology and code has been reported[1]. Shortly thereafter, an addendum report was published which described more of the features of the methodology[2]. Meanwhile, RCC has been used in a number of studies, some of which have been published[3,4,5,6].

The continued application of RCC to a variety of problem areas has led to several extensions of the RCC methodology. In particular, reliability-type failures and a very comprehensive repair/return-to-inventory model were incorporated into RCC, with concurrent, large extensions to the RCC code and corresponding output extensions. Also, the burgeoning complexity with which units are modeled has been made more easily user-handled through extensions to the RCC input formats and options.

The purpose of this report is to update RCC users on the current capabilities of RCC. As in any dynamic situation, it was necessary to choose a cut-off date for this report; 1 Jul 1980 was so chosen. Appendix A therefore contains the 1 Jul listing of RCCINFO, the mini-user's manual which is kept current in a file on the BRL computer system. Changes made subsequent to 1 Jul can be found by accessing RCCINFO, or contacting the authors.

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[1] *J. T. Klopcic, et al, " RCC: A Methodology/Code to Model Residual Combat Capability at the Unit Level", Ballistic Research Laboratory Technical Report No. ARBRL-TR-02156, April 1979.*

[2] *J. T. Klopcic, et al., Addendum to Reference 1. ARBRL-TR-02196, September 1979.*

[3] *R. A. Glacel and J. E. Schall, Jr., "TNF/S Unit Level Assessment 155mm Battery Nuclear Mission Analysis", Ballistic Research Laboratory Technical Report No. ARBRL-TR-02197, October 1979.*

[4] *J. C. Maloney and J. T. Klopcic, "Fighting Unit Survivability Evaluation (FUSE): TACFIRE System Cost-Benefit Analysis", Ballistic Research Laboratory Technical Report No. ARBRL-TR-02223, March 1980.*

[5] *J. E. Schall, Jr., et al "TNF/S Unit Level Assessment, 155mm Field Artillery Battery, Conventional Combat Analysis", TRADOC Systems Analysis Activity Technical Report, to be published.*

[6] *J. E. Schall, Jr., et al, "The Effectiveness of 155mm M109AZ 8 Gun Howitzer Battery in the Counter-Battery Role", Ballistic Research Laboratory Memorandum Report No. ARBRL-MR-03012, (April 1980).*

II. REPAIR/RETURN MODEL

Underlying the relatively complex repair/return model incorporated into RCC are the following factors which were considered important enough to maintain:

a) Repair capability is needed only if reparably damaged items are present.

b) Repair activity may compete with other activities for unit assets.

c) Therefore, a commander may decide not to repair except on a "time-available" basis.

d) The decision to use otherwise needed assets in repair roles depends upon the criticality of the item being repaired.

e) Repair completions are time distributed; i.e. a 2-hour repair may take more or less than 2 hours, with varying probabilities.

f) Items being repaired can be further damaged by subsequent incoming fire. Similarly, personnel and equipment performing the repair can become casualties.

g) Repair activity ceases during incoming fire.

h) An ongoing repair job can be pre-empted by the need to repair a higher priority item.

Furthermore, in order to preserve the ease-of-use orientation of RCC, the repair methodology should fit into the conceptual framework and input format of RCC.

Fortunately, the underlying structure of RCC proved to be broad enough to make incorporation of a suitable repair/return methodology straightforward, albeit complex. Incorporation began by recognizing that provisions already existed in RCC for capabilities whose need was dictated by run-time-occurring, code-perceived situations. Such capabilities, referred to as "dummy links", are not filled unless required. As an example, the personnel needed to manually compute fire missions might be identified as a back-up to an automatic system. RCC allows these personnel to have other tasks in other locations. However, if the automatic system fails and the RCC optimization routine identifies the (surviving) back-up personnel as the best substitute, the necessary personnel are substituted into the dummy link and redeployed at the back-up fire direction location. In the same way, RCC treats a repair as an unneeded capability until ordered (as described below). At that point, the repairing personnel and equipment are redeployed to the repair location, with transit and "get-up-to-speed" time accounted, and repair commences. The redeployed personnel are then treated by the same deployment and lethality routines that handle the user-deployed items.

Repairs can be ordered in two ways. First, the RCC optimization routine keys on the weakest link (limiting capability). When the limiting capability is vested in an item which is repairably damaged, the routine attempts to fix the item. If such fix can be made without detracting from the residual capability of the unit to do its mission (e.g. if the repair can be done by non-mission-essential elements), the repair will be ordered in that way. If, on the other hand, an additional decrement in unit performance must be taken in order to commence repair of a limiting item, the decrement is compared against the item's user-selected significance parameter. In this way, a user can choose to accept a temporary penalty in order to realize future gain, as an actual commander could do.

The second way to order repairs is on an "asset-available" basis. Having optimized the unit and assigned mission-essential tasks, the commander surveys the remaining damaged equipment. Beginning with the highest priority items, he assigns any non-mission essential personnel to repair tasks until he runs out of damaged equipment or repair assets.

In this way, the RCC Repair Methodology assures optimum allocation of repair assets, with priority to mission-limiting items, and present decrement weighed against future gain.

The repair function itself is relatively involved. Having identified and redeployed the needed repair assets, RCC starts a repair clock for each repair job. This clock is updated at each event time in the encounter, stopped during incoming fire, and restarted at each subsequent reconstitution. As mentioned above, additional damage or casualties necessitates a restart of the function.

The completion of a repair is treated probabilistically. It is assumed that actual repair times will be distributed normally, with user-input means and standard deviations for both light and medium damage. As shown by the solid curve in Figure 1, this implies an increasing probability that the repair will be completed. (In contrast, the familiar method of specifying only a mean-time-for-repair implies an "all-or-nothing" distribution, as shown by the dashed line.) RCC implements the normal distribution at each update of the repair clock. Elapsed time is fitted against the cumulative normal curve, and corresponding probabilistic increments are credited to the repair. Upper end cut-offs are implemented to preclude dedication of assets to vanishing returns.

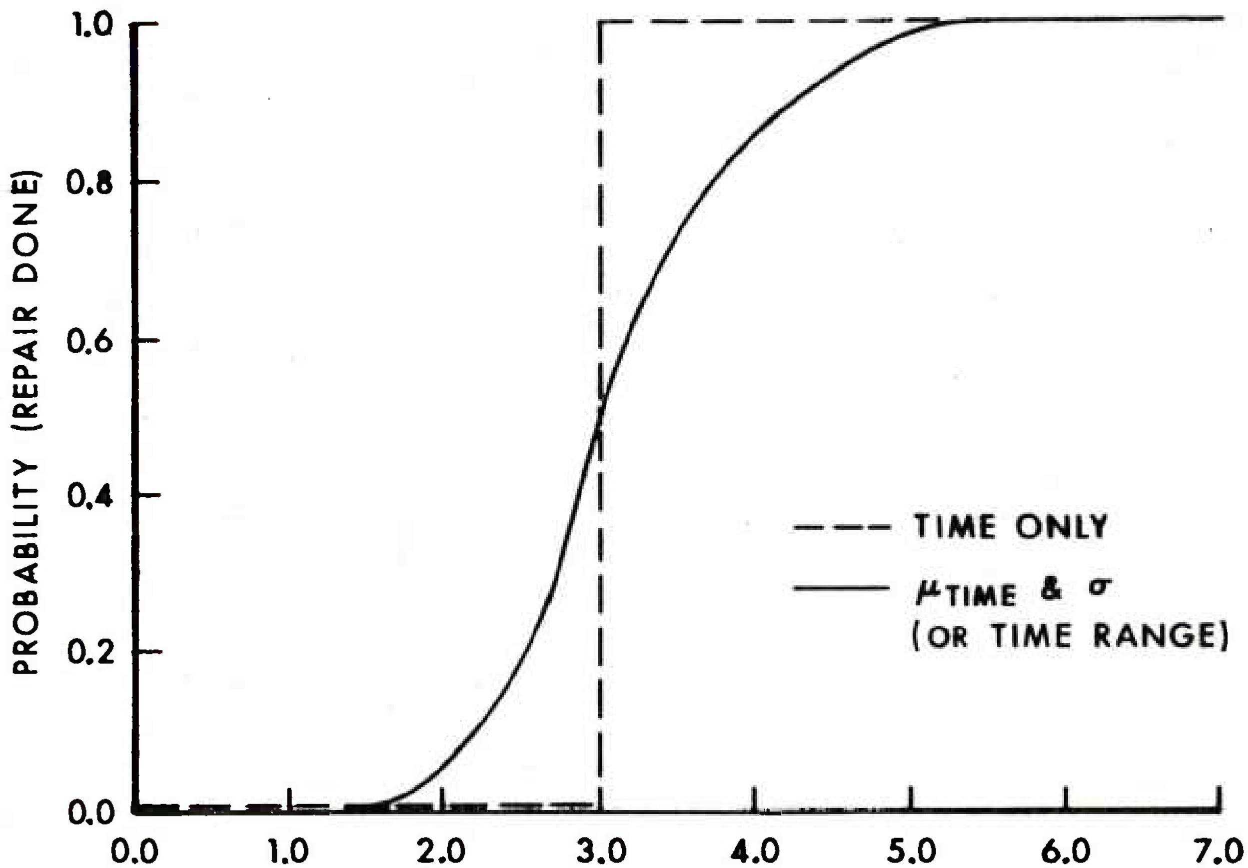

Figure 1. Repair Completion Probability: Fixed Repair Time (Dashed line) vs. Distributed Repair Time (Solid line).

Although internally complex, the user interaction with the repair model requires no changes in input technique, and relatively minor extensions of established RCC modeling concepts. Repair capability is treated as a link through the normal link input routines. Links needed for a given repair are input through the standard mnemonic input processor. The different levels of damage (light, medium, and heavy (or irreparable)) are treated as different kill criteria in the standard lethality tables. Thus, the standard lethality input routines are used. Several checks and diagnostics were built in to facilitate input debugging.

The RCC output options were expanded to support the repair model. Besides printing the normal combat capability and link usage vs. time, which reflects repair activity, RCC also outputs a synopsis of repairs ordered and completed. The detailed output options, such as the output-after-every-reconstitution option, causes detailed reporting of every repair order, status update, and return to inventory. Thus, in-depth monitoring of the repair function is available, although such detailed output is usually too copious for other than debugging applications.

III. RELIABILITY FAILURE MODEL

A straightforward exponential failure option has been incorporated into RCC. To use this option, the user inputs the (commonly available) mean time between failures (MTBF) for each item that can fail. At each event time, a Monte Carlo technique is used to identify specific failures, where each item's failure probability is a function of the ratio of elapsed time increment to the item's MTBF.

As in the repair model described previously, the inputs for reliability-failure model use the standard RCC mnemonic input processor. The outputs likewise include synopses of failures. Detailed results, toggled by the casualty-output option, are available.

IV. AUGMENTED INPUTS

Recent applications of RCC have involved some complex unit functional descriptions. For example, a recent study involved some 50 different links (capabilities) which could be chained together in 48 different ways to accomplish the unit mission (to some non-zero level). The inputting, and storage, of the large number of combinations was seen as both a nuisance and a potential source of careless errors. Therefore, the input format for links and chains was expanded to facilitate more complex unit functional descriptions. The expansion consists of creating two new input constructs, subchains and orlinks. These are defined in the following sections. For completeness, the (old) compound link construct is also discussed.

Figure 2, which will be used as an example in the following discussions, depicts a section which must receive and process information. Receiving may be accomplished through radio or telephone, either of which is manned by the radio/telephone operator (R/TO). Processing can be done by the chief and an operator using item C, or using items A and B at 70% and 30% respectively; or the chief can process it manually

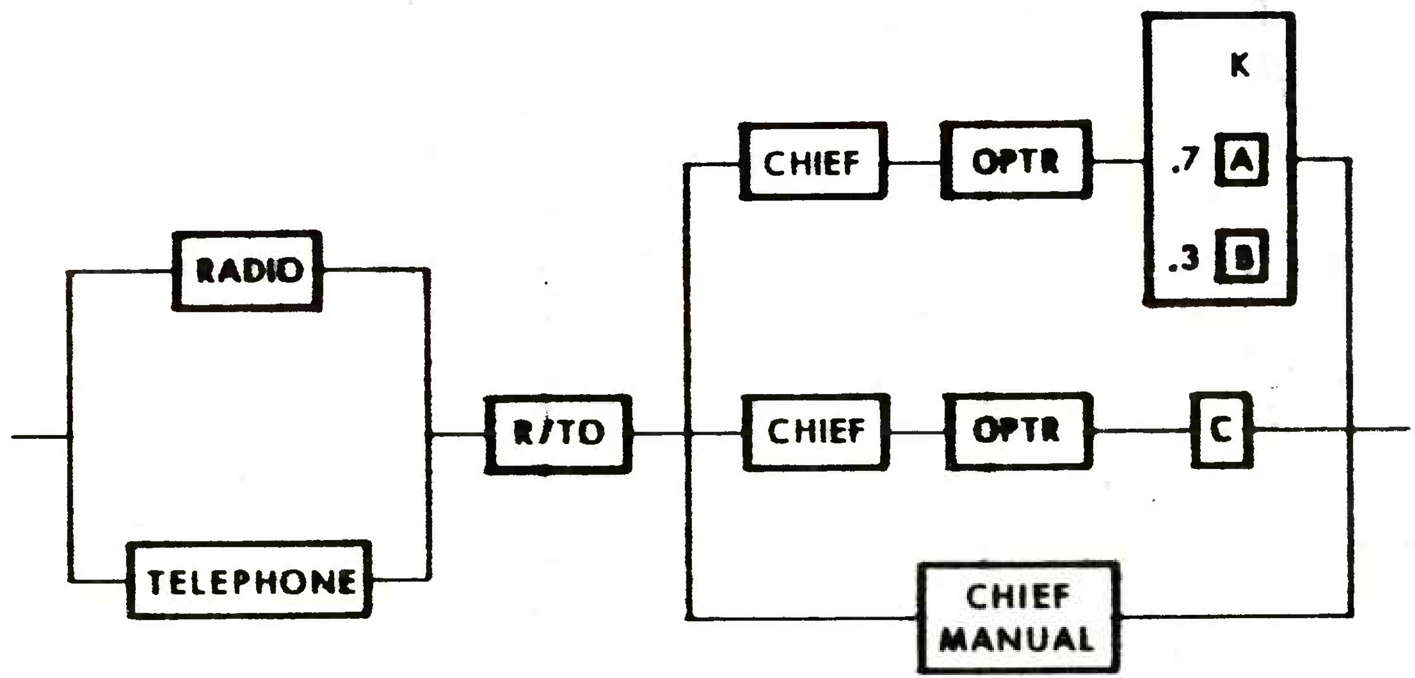

Figure 2. Example for Links/Chains Input Definition

alone. Each of the boxes represents a link in the standard RCC format: thus each box has (quantified) capability curves, optimum performance levels, time dependent substitutes, deployment checks, and output reports. For clarity, these are omitted in Figure 2.

A. SUBCHAINS

A subchain is a group of links or compound links which always must be used together. In a diagram such as Figure 2, they are always strung together. Subchains in Figure 2 are the combinations CHIEF-OPTR-C and CHIEF-OPTR-K, where K is a compound link (described below). Subchain names must be "*NUMBER". Thus, the RCC subchain input for the example would be

```
SUBCHAINS
*1, CHIEF, OPTR, C
*2, CHIEF, OPTR, K
END
```

B. ORLINKS

An orlink is a set of choices of links, compound links, and subchains for performing a particular function or set of functions. In a diagram such as Figure 2, orlinks appear as parallel strings. The parallel branches RADIO and TELEPHONE constitute an orlink. Similarly, the three parallel branches on the right, consisting of subchains *1, and *2, and link CHIEF MANUAL, constitute an orlink. Orlink names must be "+NUMBER". Thus, the RCC orlink input for the example would be:

```
ORLINKS
+1, RADIO, TELEPHONE
+2, *1, *2, CHIEF MANUAL
END
```

C. COMPOUND LINKS

Early in the development of RCC, a unit structure arose which could not be described by a simple link. The problem involved a function to which two non-interchangeable items contributed fixed amounts. For example, a firing battalion may receive 30% of its missions from division via telephone and 70% from forward observers via a special radio. Both the radio and the telephone contribute to a common function; however, they cannot substitute for one another. Furthermore, no number of telephones can produce more than 30% of the function.

To handle this situation, the compound link was established. In the above example, the radio and telephone would each be defined as normal links; the compound link input command would then compound the two together with the weighting factors .3 and .7.

The compound link input format requires name of the compound link preceded by a dollar sign (which is not part of the name.) This is followed by the links and their fractional contributions. Thus, the compound link, K, in figure 2, would be input as:

```
COMPOUND LINK
$K
 A, .7
 B, .3
 END
```

D. CHAINS

Chains can now consist of links, compound links, subchains, and orlinks. The simple example in Figure 2 would previously have required six chains. The augmented input allows Figure 2 to be specified by one chain, viz:

```
CHAINS
+1, R/TO, +2
END
```

E. ORLINK VS. SUB-ABLE SUBSTITUTE

The difference between an ORLINK and a normal link with substitution deserves to be reiterated here. An ORLINK describes a choice of using alternate CAPABILITIES or techniques. In such cases, one must be wholly employing one technique OR another, but not a combination of the two. In the preceeding example, the R/TO used the radio OR the telephone, but not some of one and some of the other. Radio and telephone constituted distinct techniques as given in the example.

A different situation often pertains, in which an ITEM (functional group) can substitute for another item to provide a measure of the SAME capability or technique. For example, a howitzer section may use a collimator or an aiming stake to hold a fixed reference direction. Both items, collimator and aiming stake, possess the same kind of CAPABILITY, although perhaps in different amounts: they are, ignoring the difference in effectiveness, interchangeable and intermixable. Thus, an eight-gun battery might replace 3 of its 8 collimators with aiming stakes if collimator replacements were unavailable. If the aiming stake is 70% as effective as a collimator and can be substituted in 2 time units, the above situation is entered into RCC using the normal LINKS input,

```
LINKS

COLLIMATOR, 8.0, 0.

$ AIMING STAKE

$ 2.

$  .7
```

On the other hand, the input

```
ORLINK

$1, COLLIMATOR, AIMING STAKE
```

implies that collimator and aiming stake have each been identified as links and that the battery uses only collimators OR only aiming stakes, at their respective link effectivenesses.

V. AUGMENTED OUTPUTS

Recent experiences have shown the need for RCC runs involving heavy, extended encounters against complex, dispersed targets. Furthermore, statistical considerations often result in the need for many replications of each encounter. These factors result in runs involving an extreme number of events. To print-out every weapon, casualty, and reconstitutional configuration for each replication is prohibitively expensive. Fortunately, such print-out is generally unnecessary; the summaries and synopses given by RCC normally supply the information desired by the user.

It can happen, however, that a particularly interesting event occurs in some replication which the user wishes to probe in detail. For example, the user may find that some link unexpectly became the weakest link in 1 out of 100 replications. The problem is to isolate the one replication for further study, without having to print out all information for all occurrences for all replications.

To this end, the TRACE, PARTICULAR CASUALTY, and DUMP8 options were added. At present, two TRACE options are available: trace weakest link and trace link uses. When activated, the option prints out the replication and reconstitution numbers in which the designated links are weakest/used. When used in conjunction with the RANDOM output option*, TRACE allows the user to replay, with fully detailed print-out, just that replication which contains the event of interest.

**See Appendix A for explanation of options.*

The formats for the TRACE option are:

```
TRACE

WEAK LINK, link name, ALL

WEAK LINK, link name, reconstitution number

USES, link name, ALL

USES, link name, reconstitution number

...................

...................

...................

END
```

Similarly, RCC now contains a PARTICULAR CASUALTY option, allowing detailed print-out of casualty events for specified functional groups. This option, too, allows extracting a pre-selected portion of the mass of statistically generated data from a complex RCC run.

Finally, RCC also allows saving a one-line synopsis of time, effectiveness, weakest link and strongest chain for every reconstitution. This option, called DUMP8 in the OUTPUT OPTION set, writes formatted records onto file 8. These can later be interrogated and/or printed by the user after the run.

VI. INTERFACING

An effort that is currently receiving a fair amount of attention is in the area of interfacing RCC data with broadscale (e.g. division-level) war-games. RCC is designed to model small units in detail. However, no attempt is made to model those phenomena which happen on a large scale nor to include two-sided effects (e.g. BLUE cannot defend himself by shooting RED first.) Rather, as shown in Figure 3, the place of RCC is to take broad-scale-model-generated situations, examine in detail the effects of those situations on individual units, and put out results to be used by subsequent broad-scale analyses.

Ideally, one would like to generate a vehicle (look-up tables or parametric equations) which a broad-scale model could access with scenario parameters and retrieve effectiveness indicators. Unfortunately, the effectiveness of a unit is dependent not only upon a large number of variable scenario parameters (e. g. number and type of incoming rounds, target location and delivery errors, aimpoint, deployment, lethalities, mission and organization), but also upon the specific items lost in previous engagements. While it may be

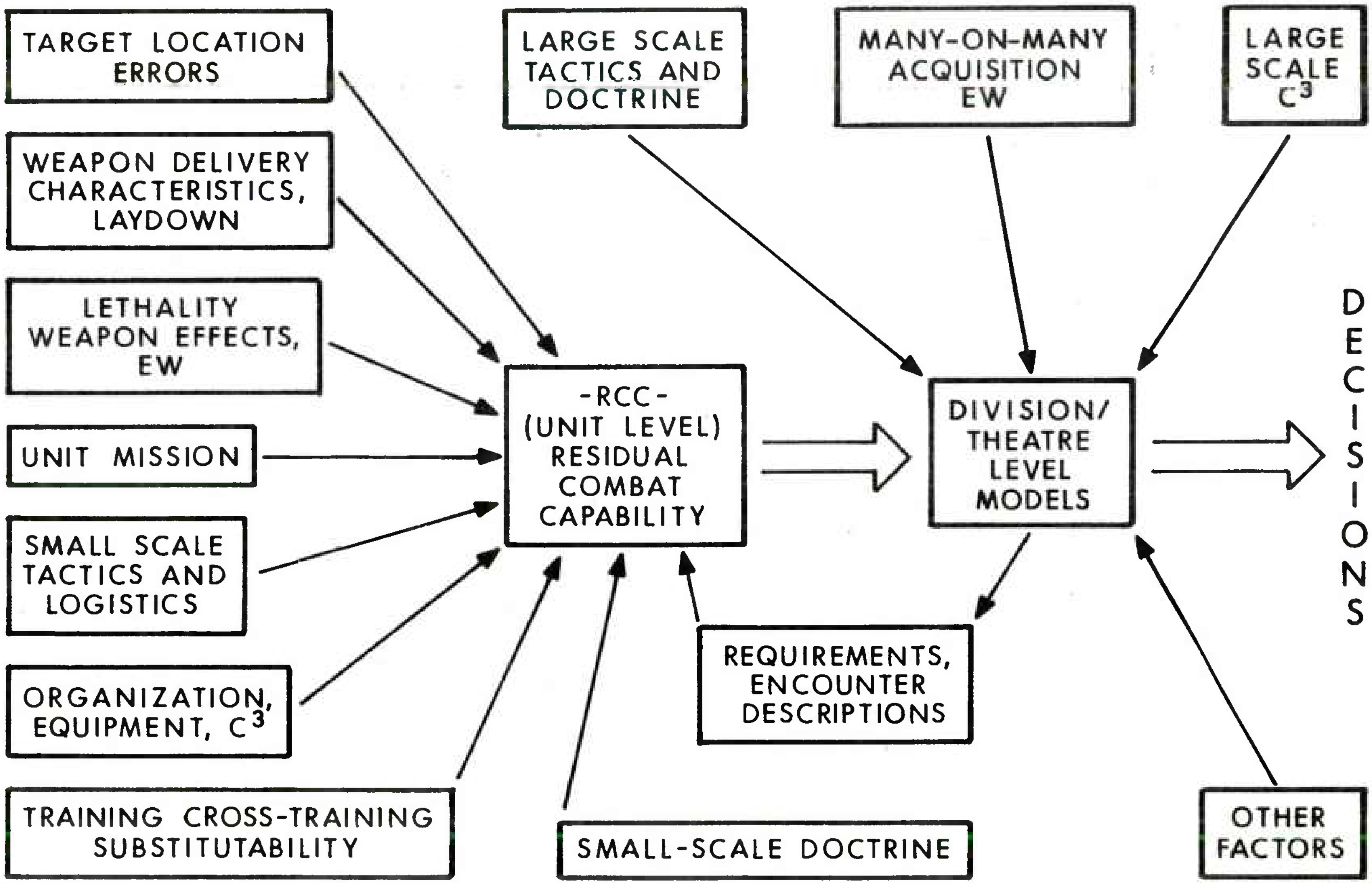

Figure 3. Position of RCC in Broad Scale Analyses

possible to develop some coarse guidelines for effectiveness loss versus scenario parameters, a general technique for storing effectiveness versus all scenario parameters for all unit conditions seems impractical to develop.

We are therefore pursuing a less general interface, in which specific sets of scenario parameters for specific units are extracted from a broad-scale study, played through RCC, and then reinserted in a second iteration of the broad-scale study. Such an interface is graphically depicted in Figure 4. The division level model, which includes models of two-sided maneuver, acquistion, fire planning, etc., is run through the "zeroeth" iteration. Such models must have some sort of attrition model also, in order to model engagement outcomes. Thus, the division-level model can play through to the end of the scenario. Each time a BLUE unit is engaged, the scenario parameters are recorded on an auxiliary file. This auxiliary file, containing the specific history for each unit, becomes the input for RCC analyses of each unit. These RCC analyses are made employing the usual full detail. The RCC effectiveness results, in turn, are inserted into the auxiliary file, and the file re-read by the division-level model for its next iteration. During this iteration of the division-level model, the parameters that are generated for each encounter are compared against those in the auxiliary file. If the encounter and auxiliary file (RCC) parameters match, the RCC-generated effectiveness results are used by the division-level model. If a mismatch occurs, the division-level model sets a flag for the unit and reverts to its own attrition model. Meanwhile, the division-level model is creating a new auxiliary file to serve as input for the next RCC/division-level-model iteration cycle.

Two factors result in rapid convergence of the RCC/division-level iterations. First, the scenario parameters generated by the division-level model for an encounter against a BLUE unit do not depend directly upon BLUE effectiveness, except in the case that BLUE effectiveness is below the minimum required for BLUE to fire and be detected. Thus, with the exception noted, BLUE effectivness affects the scenario parameters only by an indirect chain of events; viz. BLUE's previous effectiveness, if used against RED artillery, may reduce the amount of RED capability which may change future scenario parameters. The second factor leading to rapid convergence is the ability of the division-level analyst to adjust his attrition model to more closely parallel the RCC results. Convergence is, of course, guaranteed: Each iteration must add at least one additional encounter for which the preceding history is identical with the corresponding history in the previous iteration. Thus each iteration must agree on at least one additional set of parameters. However, the above two factors combine to insure convergence much more rapidly than one encounter per iteration.

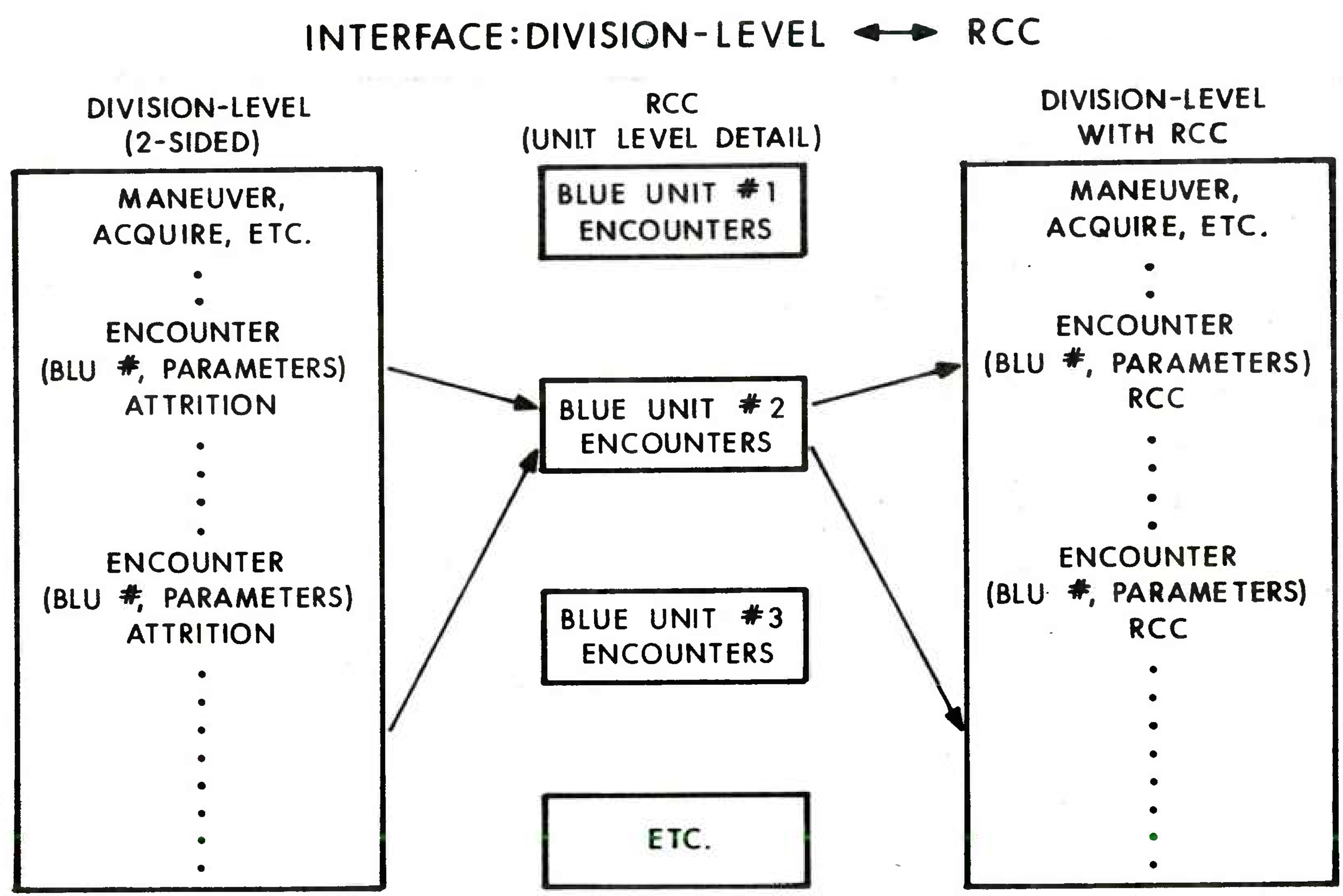

Figure 4. Graphical Representation of an Iterative Interface

The benefits of interfacing are currently being felt in the ARRADCOM Enhanced Self Propelled Weapon System (ESPAWS) study. Under Mr. E. Stauch of AMSAA, the AFSM[7] model was interfaced with RCC by Mr. R. Sandmeyer. The AFSM-RCC results showed some important deviations from the pureattrition model (AFSM alone) results.[8] The AFSM-RCC results were subsequently used to guide RCC sensitivity tests and to adjust the AFSM attrition model.

VII. SUMMARY

The updates reported here were all incorporated into RCC and tested by 1 Jul 80. Certain other control and output options, such as selective deployment plotting, have also been added since the preceding RCC methodology report (ref. 2) was written. These are listed in Appendix A, and warrant no further discussion. Several internal simplifications and optimizations have also been made to the RCC code. However, these are not of sufficient interest to the user to warrent listing here.

Several studies have been reported which used the RCC code. Current studies include those required for the ESPAWS project under ARRADCOM, logistical unit studies for LOGCNTR, and certain RED support unit studies being conducted by AMSAA.

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[7] *R.S. Sandmeyer, "Artillery Force Simulation Model User Manual", Army Material Systems Analysis Agency Technical Report No. 263. January 1979.*

[8] *ESPAWS Baseline Case Evaluation Study report, to be published.*

APPENDIX A

LISTING OF RCCINFO

This appendix contains a listing of the source file RCCINFO, a brief, current user's manual for the RCC code.

```
                         INPUT INFO FOR RCC
                         *************

                         GENERAL COMMENTS
                         ................

         RCC INPUTS ARE ALL MNEMONIC AND FREE-FIELD ( AND MACHINE INDEPENDENT, ALMOST ).  THREE FORMS OF INPUT ARE SOLICITED
ALL HOLLERITH, ONE HOLLERITH NAME ( TWO WORDS ) FOLLOWED BY NUMBERS ( FIXED AND F.P., MIXED ), AND ALL NUMBERS.
HOLLERITH STRINGS ARE SEPARARTED BY COMMAS. NUMBERS BY COMMAS OR SPACES.  LEADING BLANKS ARE IGNORED.
         THE GENERAL FORM OF A RUNSTREAM IS AS FOLLOWS
REPERTOIRE:  ALL NAMES TO BE USED FOR FUNCTIONAL GROUPS AND WEAPONS
END
ENCOUNTER1 INPUTS:  ALL OTHER DATA, INCLUDING PROGRAM CONTROLS, FOR THE ENCOUNTER.  STANDARD FORM IS:
     MNEMONIC  -  TO INDICATE TYPE OF DATA
     DATA
     END
( NOTE, HOWEVER, THAT RCC TRIES VERY HARD TO COMPENSATE FOR MISSING END CARDS. AT PRESENT, ONLY THE END
  CARD AFTER THE REPERTOIRE IS ESSENTIAL )
AFTER THE DATA IS IN:
GO      THE PROGRAM EXECUTES ONE ENCOUNTER AND RETURNS FOR NEW ENCOUNTER INPUTS
STOP    ENDS PROGRAM
SPECIAL FEATURE: A CARD BEGINNING WITH A DOLLAR SIGN, $, IS INTERPRETED AS A CONTINUATION CARD, IF POSSIBLE.
IF NOT, IT IS REINTERPRETED AS A COMMENT CARD.  HENCE, FOR EXAMPLE, COMMENTS CAN BE INSERTED IN THE RUNSTREAM
AFTER ANY END CARD.
COMMENTS CAN ALSO BE INSERTED ON ANY CARD AFTER THE CARD'S DATA BY USING A $. ANY $ AFTER COLUMN ONE ENDS SCAN OF THAT CARD


  ** ANY ITEM IN SQUARE BRACKETS [ ] IS NOT ESSENTIAL TO THE INPUT FORMAT, BUT CONVEYS ADDED
    INFORMATION.  NESTED BRACKETS INDICATE OPTIONS W/IN OPTIONS. PARENTHESES ( ) ENCLOSE COMMENTS FOR THIS LISTING **


                         REPERTOIRE INPUT
                         ****************

                         FORMAT
                         ......

WEAPON
WEAPON NAME1 [, ALT. NAME, ALT. NAME, .... ]
WEAPON NAME2 [, ALT. NAME, ALT. NAME, .... ]
WEAPON NAME3 [, ALT. NAME, ALT. NAME, .... ]
.............
FUNCTIONAL GROUP    ( OR FG OR FGS )
FUNCTIONAL GROUP NAME1 [, ALT. NAME, ALT. NAME, .... ]
FUNCTIONAL GROUP NAME2 [, ALT. NAME, ALT. NAME, .... ]
FUNCTIONAL GROUP NAME3 [, ALT. NAME, ALT. NAME, .... ]
 .........
END

                         COMMENTS ON REPERTOIRE INPUT
                         ............................

1. SOME NAMES MAY BE COMMON TO SEVERAL FG S OR WEAPONS.  THIS ALLOWS SUBSCRIBING A COMMON CHARACTERISTIC
   TO SEVERAL ITEMS BY ATTACHING THE CHARACTERISTIC TO THE COMMON NAME.
2. FG OR WEAPON NAMES MAY BE INPUT IN ANY ORDER, OR MIXED, AS LONG AS AN FG OR WEAPON CARD PRECEDES THE NAMES.
3. FOR SECONDARY EXPLOSION, COLOCATE EXPLOSIVE WITH TARGET. EXPLOSIVE MUST APPEAR IN BOTH TARGET AND WEAPON REPERTOIRE LISTS.

                         ENCOUNTER INPUTS
                         ****************
```

```
                        FORMAT
                        ......
NOTE:  TIMES ARE IDENTIFIES AS ENCOUNTER TIME (CLOCK) OR TIME INTERVALS (INTRVL) - USED TO INPUT A PERIOD OF TIME AFTER AN EVENT
MNEMONIC                SUBSEQUENT DATA CARDS
.....................................................................................................................................

                        UNIT INPUTS
                        ...........

CHAINS                  LINKS, ORLINKS, AND/OR SUBCHAINS - ( HOLLERITH ) NAMES IN EACH CHAIN
                        LINKS MUST BE DEFINED PRIOR TO USE IN 'CHAINS' INPUT. SEE LINKS BELOW
                        'CLEAR' WILL CLEAR ALL PREVIOUS CHAINS
COMPOUND LINK           *COMPOUND LINK NAME
                        LINK, ( REAL ) MAXIMUM CONTRIBUTION OF THIS LINK
                        LINK, ( REAL ) MAXIMUM CONTRIBUTION OF THIS LINK
                        .....
DEPLOY                  FG,X,Y OF TARGET POINT, [-] NO. THERE, CONV. KILL CRITERION, NUCLEAR K.C., POSTURE CODE, NUC COVER CODE
                        ( NEGATIVE NO. THERE INDICATES A DUMMY TARGET )
                               FOR SECONDARY EXPLOSIVE SOURCE, PUT KILL CRITERIA ( BOTH CONV. AND NUCL. ) = 0.
                               ( UNDERSTOOD IN LETHALITY ( UNIT 2. ) THAT ONE CRIT. ( EXPLODE ) PERTAINS )
DUCK!                   FG,TIME(INTRVL) TO DUCK,FROM CONV. POSTR,FROM NUCVR,TO CONV. POSTR,TO NUCVR
FAILURE RATE            FG. MTBF ( MEAN TIME BETWEEN FAILURES ),%LITE,%MEDIUM ( MUST BE REPAIRABLE ( SEE BELOW ) IF %S .NE. 0 )
FATIGUE                 LINK NAME, TIME, NEW CAP100%, CAP0%, MAXEFF%
                        ( SEE LINKS, BELOW )
LINKS                   LINK NAME(-NAME OF HOMELINK FG), (REAL) NO. OF FG FOR 100% CAP., 0 % CAP.[,MAX. EFF.]
                        ( IF 1 INTEGER, TAKEN AS REMAINING CAP. AT 0. SURV. )
                        ( IF NO MAX. EFFECTIVENESS, MAX EFF = 1. )
                        [$,FGSUB1,FGSUB2,.... ( SUBSTITUTES )]
                        [[$,] ST1,ST2,.... ( SUBSTITUTION TIMES(INTRVL) )]
                        ( EACH SUBSTITUTE CARD MUST BE FOLLOWED BY A SUBST. TIMES CARD )
                        'CLEAR' WILL CLEAR ALL PREVIOUS LINKS
LOSSES                  FG LOST, TIME(CLOCK) OF LOSS, NUMBER OF THEM
ORLINKS                 +NUMBER( ORLINK NAME MUST BE +NO., NO.=1-23 ), LINKS (AND/OR SUBCHAINS) TO BE OR'ED
REINFORCEMENTS          FG REINFORCING, TIME(CLOCK) OF ARRIVAL, NUMBER OF THEM
REPAIR                  FG, PNLT, MEAN TIME FOR LITE DMG. REPAIR, STND. DEV. IN TIME, MEAN TIME FOR MEDIUM, STND. DEV.
                        ( PNLT IS LOSS IN % EFFECTIVENESS FOR IMMEDIATE MISSION WHICH WILL BE ACCEPTED
                          IN ORDER TO FIX THIS FG, IF IT IS THE WEAKEST LINK )
                        [$], LINKS NEEDED FOR LITE REPAIR ( .LE. 3 )
                        [$], LINKS NEEDED FOR MEDIUM REPAIR ( .LE. 3 )
                        [ NOTE: LETHALITY DATA FOR REPAIRABLE FG MUST HAVE EXACTLY 3 KILL CRITERIA, VIZ
                                UNREPAIRABLE, MEDIUM, LITE RESPECTIVELY. SEE CONVENTIONAL LETHALITY, BELOW ]
SIGNIFICANCE            FRACTIONAL AMOUNT OF IMPROVEMENT NEEDED BEFORE COMMANDER WILL VIOLATE PRIORITY IN SUBSTITUTION
SUBCHAINS               %NUMBER( SUBCHAIN NAME MUST BE %NO., NO.=1-26 ), LINKS TO BE SUBCHAINED

                        WEAPON INPUTS
                        .............

DELIVERY ERROR          WEAPON NAME, [ TIME(CLOCK), ] RANGE ERRORS - INDEP., CORR., DEFLECTION ERRORS - INDEP., CORR., HOB ERROR

                        ** NOTE: IN RCC, ALL ERRORS ARE INPUT AS SINGLE AXIS STANDARD DEVIATIONS ( = SQRT( VARIANCE, 1-AXIS ) ) **
                        **         OR ELSE, AS CEP. ( INPUT -CEP ( NEGATIVE ) FOR BOTH X AND Y ERRORS. PROGRAM CONVERTS TO S.D.
                        ** NOTE: IF TIME IS PRESENT, INPUT IS AN EVENT ( CHANGE IN VALUE DURING ENCOUNTER ). ELSE = INITIAL VALUE

ROUND                   WEAPON NAME, TIME(CLOCK), DGZ X, Y, Z
TLE                     [ TIME(CLOCK), ] ERRORX AND ERRORY   SEE NOTE ON ERROR FORM, ABOVE
VOLLEY                  WPN NAME, TIME(CLOCK), PATTERN MIDPT - X, Y, Z, NO. RNDS, DIRECTION OF PATTERN - DEG., LENGTH OF PATTERN
                        [ $ , TOTAL DURATION, TIME(INTRVL) BETWEEN VOLLEYS, DIRECTION OF MOVE OF MIDPT., DISTANCE OF MOVE ]
                             ( THIS ALLOWS INPUT OF A MOVING BARRAGE )
                         NOTE:  DIRECTION ANGLE IS MEASURED CCW FROM +X ( FRONT TO REAR )
```

```
                                  LETHALITY INPUTS
                                  ................

CONVENTIONAL                      NO DATA FOLLOWS IN RUNSTREAM - DATA READ FROM UNIT 2 ( SEE CONVENTIONAL DATA, BELOW )
CUMULATIVE DOSE                   FG, DOSE LEVEL FOR CUMULATIVE DOSE CASUALTY
                                 OPTIONS: ALL, LEVEL ( SETS ALL FGS TO SAME CUM.DOSE KILL LEVEL )
                                          NONE  ( TURNS OFF CUMULATIVE DOSE KILL )
                                 DEFAULT IS LOWEST DOSE LEVEL OF ANY LINK IN WHICH FG CAN SERVE ( FROM DEPLOYMENT )
LD50                              DESCRIPTION ( <- 12 CHARACTER HOLLERITH STRING ), KILL CRITERION ( 1-5 ), LD50
                                  ( KILL CRITERION 0 IS FOR CUMULATIVE DOSE )
NUCLEAR                           NO DATA FOLLOWS IN RUNSTREAM - DATA READ FROM UNIT 3 ( SEE NUCLEAR DATA, BELOW )
SHIELDING                         DESCRIPTION ( <= 12 CHARACTER HOLLERITH STRING ), USER-CHOSEN CODE ( 1 - 61 ), TRANSMISSION FACTOR
YIELD                             WEAPON NAME, YIELD ( KT - USED IN NUC ONLY )

                                  CONTROL INPUTS
                                  ..............

GO                                NO DATA FOLLOWS - CAUSES ENCOUNTER EXECUTION
HEADING                           READ ONE HOLLERITH STRING - ENCOUNTER OUTPUT HEADING
INPUT                             OPTION, 'ON' OR 'OFF'
                                  OPTIONS: DEBUG ( PROCESS INPUT, BUT DO NOT EXECUTE )
INTERNAL RECONS. TIME             TIMES(INTRVL)( REAL ) AFTER ARRIVAL OF  RND AT WHICH RECONSTITUTION IS TO BE EVALUATED ( .LE. 11 INTRVLS )
                                          RECONSTITUION SURPRESSED IF ANOTHER RND ARRIVES IN THE MEANTIME
OUTPUT OPTIONS                    OPTION, 'ON' OR 'OFF'
                                  OPTIONS: (OUTPUT AFTER EACH:) ITERATION, RECONSTITUTION, WEAPON DELIVERY, CASUALTIES,
                                           PRINT7 ( PRINT ON ALT. PRNT. FILE 7 )
                                           DOSE  (NUCLEAR), LETHALITY (LISTING OF TAPE 2 AT END OF RUN), DEPLOYMENT PLOT ( DEFAULT=ON )
                                           SUMMARY ( NAME1, NAME2 / OR SUMMARY, OFF ( SUM OF SURVIVORS HAVING SAME NAME ( MAX 13 ) ) )
                                           LINK SUMMARY ( LINK1, LINK2 / OR LINK SUMMARY, OFF ( NO. TIMES WEAKEST BY CHAIN ( MAX 12 ) ) )
                                           REPAIR REPORT ( ALL REPAIR ORDERS AND RETURNS ), RANDOM NUMBER ( AT START OF EA. ITER. )
                                           DUMP8 ( WRITES - ON TAPE8 - TIME, EFF.,WK LNK, STR CHN FOR EVERY RECONST. )
PARTICULAR CASUALTY REPORT  NAMES OF FGS TO BE INCLUDED IN CASUALTY REPORTS. 'CLEAR' REMOVES THE OPTION
RANDOM NUMBER SEED                INTEGER R.N. SEED FOR ENCOUNTER - ALLOWS RUNNING NEW ENCOUNTER W/ SAME R.N.S
RECONSTITUTION EVENT              TIME - INSERTS A NUL LETHALITY EVENT, CAUSING RECONS. AT TIME INTERVALS SPECIFIED UNDER INTERNAL
REPLICATIONS                      NO. OF REPLICATIONS PER ENCOUNTER
SELECTIVE DEPLOYMENT PLOT    NAMES OF FUNCTIONAL GROUPS TO BE INCLUDED IN DEPLOYMENT PLOT. 'CLEAR' REMOVES THE OPTION
STOP                                END OF RUN. NO INPUT FOLLOWS
SUBSEQUENT MISSION                NO DATA FOLLOWS THIS CARD - AFTER ENCOUNTER, SURVIVORS ARE SAVED.
                                  AFTER 'GO' CARD, NEW LINKS, CHAINS, HEADINGS CAN BE INPUT FOR OPTIMIZATION
                                  END SUCH INPUT WITH ANOTHER 'GO'. SUBSEQUENT MISSIONS CAN BE LINKED
TRACE                             ( THIS OPTION REPORTS OCCURANCES OF USER SPECIFIED EVENTS )
                                  ( WHEN USED IN CONJUNCTION WITH THE RANDOM OPTION ( UNDER OUTPUT ), TRACE AIDS THE USER IN
                                  REPLAYING SPECIFIC REPLICATIONS OF INTEREST )
                                  ( INPUT DEPENDS ON OCCURANCE TYPE BEING TRACED. TO WIT : )
                                  'WEAK LINK', LINK NAME, RECONST. NO. OR 'ANY' ( REPORTS OCCURANCES OF SPECIFIED LINK BEING WEAKEST )
                                  'USES', LINK NAME, RECONST. NO. OR 'ANY' ( REPORTS OCCURANCES OF SPECIFIED LINK BEING USED )

                                  CONVENTIONAL LETHALITY DATA ( UNIT 2 )
                                  **************************************

WEAPON
WEAPON PARAMETERS ( FROM SANDMEYER, AMSAA )
                                  CARD 1: 8 (REAL) VALUES
                                  CARD 2: 4 (REAL) VALUES
                                  CARD 3: A6, I6  ( IF A6 .NE. 3HICM, I6 IS MEANINGLESS AND DO NOT READ CARDS 4 AND 5 )
                                  CARD 4: 5 ( REAL ) ICM VALUES
                                  CARD 5: 10 ( REAL ) ICM VALUES
TARGET, DATA TYPE : 2 - CARLETON FUNCTION, 3 = 1-CONTOUR COOKIE CUTTER, 4 = ICM, 5 = 2-CONTOUR COOKIE
                  : 6 = 3-COOKIE, 7 = FRONT/BACK ASYMETRIC CARLTON
```

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                  : 8 = ASYM. 1-COOKIE , 9 = ASYM. 2-COOKIE, 1- = ASYM. 3-COOKIE
                  : ( ASYM. FORMAT: RX FOR TRGT X ) BURST, RY, RX FOR TRGT X ( BURST )
NHOB. NOMINAL HOB VALUE FOR WHICH EACH LETHALITY APPLIES
      ( RCC CONSTRUCTS RANGES ABOUT EACH HOB TO INTERPOLATE FOR ANY HOB )
NPOSTURES, DESCRIPTIONS
NKILLCRITERIA, DESCRIPTIONS
     .............................................
     ...NHOB*NPOSTURES*NKILLCRITERIA DATA CARDS...
     ...EACH DATA CARD CONTAINS:...
                        DATA TYPE 2: 3 ( REAL ) VALUES
                        DATA TYPE 3: 3 ( REAL ) VALUES - PK, RX, RY
                        DATA TYPE 4: 1 ( REAL ) VALUES
                        DATA TYPE 5: 6 ( REAL ) VALUES
                        DATA TYPE 6: 9 ( REAL ) VALUES
                        DATA TYPE 7: 4 ( REAL ) VALUES
                        DATA TYPE 8: 4 ( REAL ) VALUES - PK, RX, RY, RXP
                        DATA TYPE 9: 8 ( REAL ) VALUES
                        DATA TYPE 10: 12 ( REAL ) VALUES
     .............................................

 LOOP BACK FOR NEW TARGET
END - LOOP BACK FOR NEW WEAPON
END - EXIT BACK TO MAIN ROUTINE


                        NUCLEAR VULNERABILITY DATA ( UNIT 3 )
                        *************************************

TARGET ( FG ), CODE, DATA ( AS REQUIRED BY CODE )
                        CODES:  1 = EMP, 2 = TREE, 3 = 1+2, 4 = BLAST, 5 = 1+4, 6 = 2+4, 7 = 1+2+4
                        DATA: AS SPECIFIED BY NUDACC
                              EMP: MU AND SIGMA
                              TREE: T2, MU, AND SIGMA
                              BLAST: K, MU, AND SIGMA
                        ORDER: AS NEEDED, EMP, THEN TREE, THEN BLAST

                        *** AUXILIARY PROGRAM RCCFILE.4T03 ***
     MAINTAINS DATA BASE UNIT 4 ( NUDACCDATA )
     MAKES FILE 3 IN PROPER FORMAT FOR RCC RUNS
     XQT 4T03RB. INSTRUCTIONS APPEAR INTERACTIVELY

COMMAND-
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